Today's Agenda

Final project presentation & report

Region-based segmentation

Morphological image processing techniques

Final Exam Schedule

Final exam has been scheduled:

12:30 p.m. – 3:00 p.m., Monday, April 29

Requirement:

- **Closed book and closed notes**
- **One-page double-sided cheat sheet is allowed**
- **A calculator is allowed for +-*/**

It will cover all the topics discussed in class

Final-Project Presentation

- **Team project – a single presentation**: each team has 13 minutes (11.5 minutes for presentation and 1.5 minute for questions) to present your project.
  - Both members should take part in the presentation.
- **Single person project**: Each student has 11 minutes (10 minutes for presentation and 1 minute for questions) to present your project.

Final-Project Presentation

Presentation days:

- Monday, April 15
- Wednesday, April 17
- Monday, April 22

Send me an email (tongy@cse.sc.edu) by 11:59pm, April 9 including preference of these three days in a decreasing order. Earlier email has higher priority in choosing the day

What Should Be Included In the Final-Project Presentation

For a research/hands-on project

- An introduction of the background
- A brief literature review
- Methodology of your proposed method
- Experiment setup: dataset, evaluation metrics, etc.
- Experimental results if any
- Conclusion
- Reference list

Note: You don’t need to have the experimental results by presentation date, but you need to include the information about the experimental setup and implementation details.

What Should Be Included In the Final-Project Presentation

For a survey project

- An introduction of the background
- An organized structure of the papers
- Comparison and critical comments of the methods/groups you reviewed
- Conclusion
- Reference list

Note: You don’t need to complete the survey project by presentation date, but you need to show how you organize your papers. You can cover part of the papers in your full list.

Final Presentation Criteria

Category	Description	Worth
Description of Problem	Did you make clear the nature of the problem you were trying to solve?	15
Description of Methodology (Research project)	Did you present the methodology clearly? Did you provide sufficient (key) information to the audience?	25
Description of Experiment (Research project)	Could your experiment design – dataset, evaluation metrics, baseline approaches effectively demonstrate your proposed method?	25
Discussion and Comparison (Survey project)	Did your discussion clearly show your understanding of the methods? Did you make critical comments on the methods?	50
Visual Aids	Were visual aids used effectively? Were slides clear and easy to read by the audience?	10
Clarity & Organization	Was the presentation easy to understand; did it have a logical flow and organization?	15
Timing	Was the presentation well-paced? Did it fit within the time allotted?	10

On the Final Project Report

Written report due time: 11:59pm. April 29th

- Report format: the same as a conference paper
  - For example, you can use a template for ICIP 2023

    Information for Authors – 2023 IEEE International Conference on Image Processing (ieeeicip.org)

    - You need to follow a formal citation format, e.g., IEEE format

    Length: around 4 pages double-column (+ reference, no page limit on the reference)
- Code must be submitted with clear comments (Research project only)

Academic integrity (avoiding plagiarism)

- don't copy other person's work
- describe using your own words
- complete citation and acknowledgement whenever you use any other work (either published or online)

Requirement for Final Project

In form of a complete research project

- Introduction (problem formulation/definition)
- A brief literature review
- The proposed method and analysis
- Experiment including experiment setup and experimental results
- Conclusion
- Reference

A survey research

- A well-defined problem or topic
- An organized structure of the reviewed papers
- Analyze/discuss these methods and compare them, preferred in groups
- Conclusion
- Reference

Note: you need to include >=15 references

Final Project Report Grading Criteria

Category	Description	Worth
Description of Problem	Did you make clear the nature of the problem you were trying to solve?	10
Description of Methodology (Research project)	Did you present the methodology clearly? Did you provide sufficient (key) information to the readers?	35
Description of Experiment (Research project)	Could your experiments effectively demonstrate your proposed method?	30
Discussion and Comparison (Survey project)	Was the problem comprehensively reviewed? Did your discussion clearly show your understanding of the methods? Did you make critical comments on the methods you reviewed? Were the reviewed papers well organized? Did you show the connections among the papers?	65
Writing Clarity	Does the report read well? Is it easy to understand?	10
Organization & Length	Is the report well-organized? Does it have a logical flow?	10
Reference	Is the reference section complete and in consistent format; are the citations in the text in consistent format?	5

Image Segmentation

(a) $\bigcup_{i=1}^{n} R_i = R$

(b) R_i is a connected set, $i = 1,...,n$

(c) $R_i \cap R_j = \phi, \forall i \neq j$

(d) $Q(R_i) = TRUE$

(e) $Q(R_i \cup R_j) = FALSE$ for adjacent regions R_i and R_j

Two categories based on intensity properties:

- Discontinuity – edge-based algorithms
- Similarity – region-based algorithms

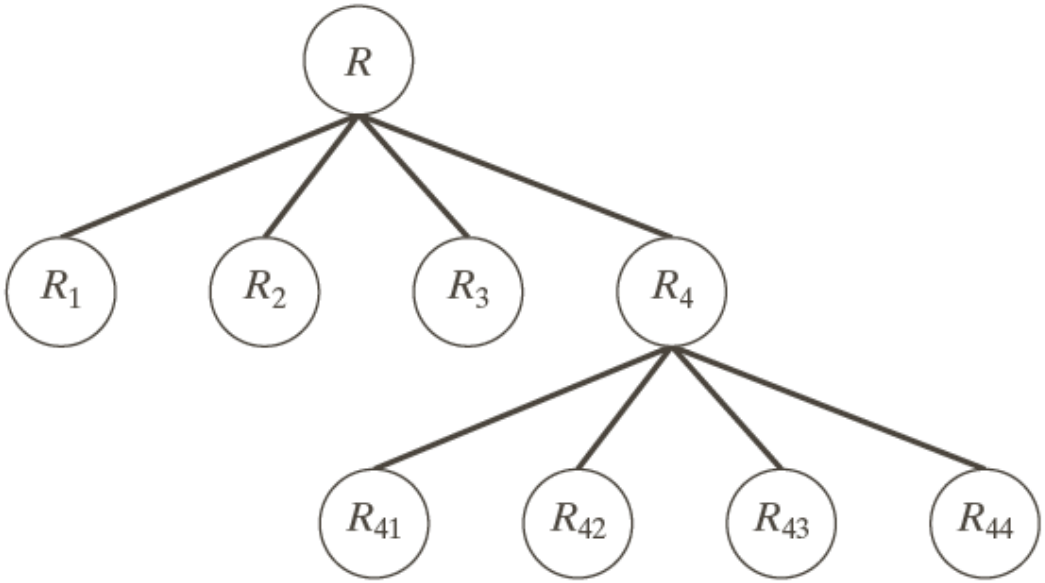
Region-Based Segmentation

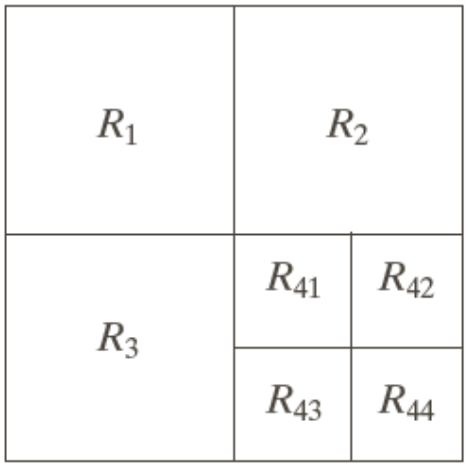
- Region growing
- **Region splitting and merging**

Region-Splitting and Merging Algorithm

Step1: Keep splitting the region while $Q(R_i) = FALSE$ and $R_i > \min Size$

Step 2: Merge the subregions while $Q(R_i \cup R_j) = TRUE$

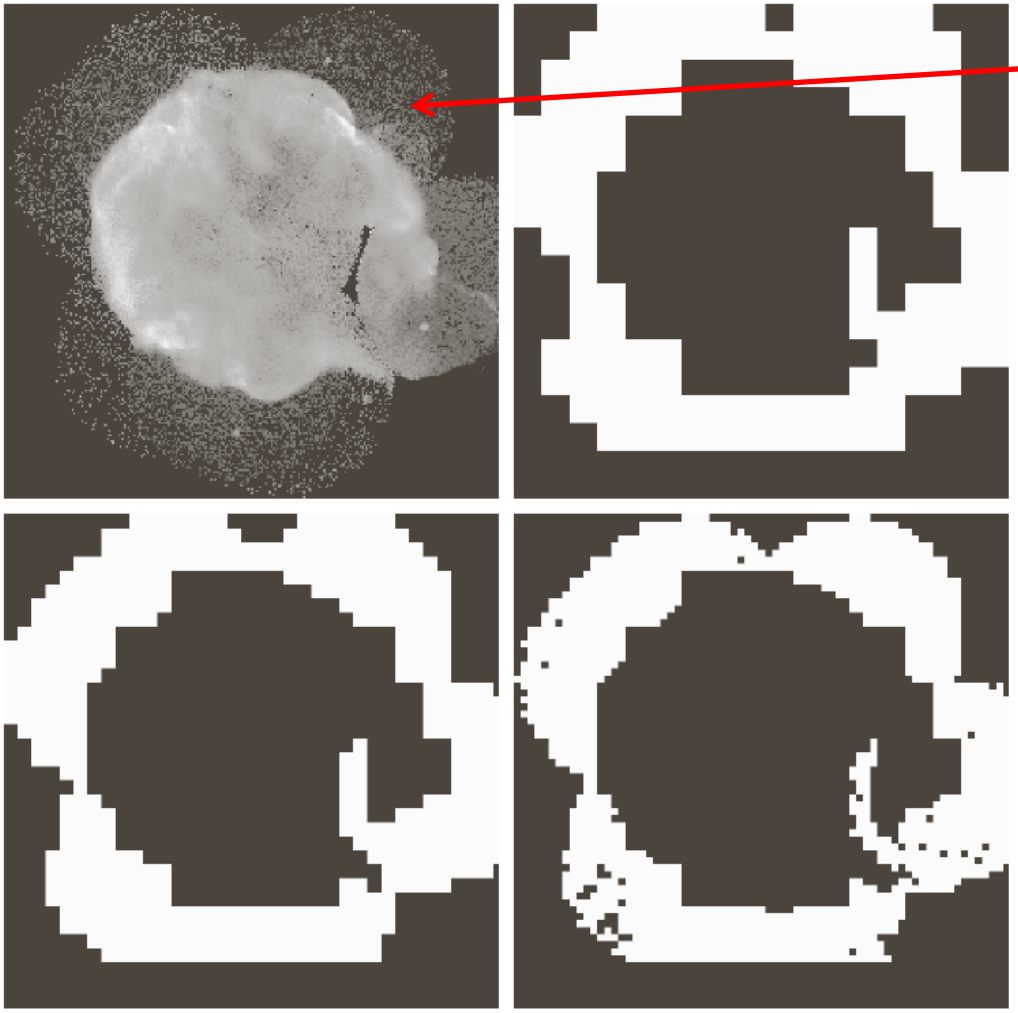




a b

FIGURE 10.52
(a) Partitioned image.
(b) Corresponding quadtree. R represents the entire image region.

An Example



a b
c d

FIGURE 10.53 (a) Image of the Cygnus Loop supernova, taken in the X-ray band by NASA's Hubble Telescope. (b)–(d) Results of limiting the smallest allowed quadregion to sizes of 32×32, 16×16, and 8×8 pixels, respectively. (Original image courtesy of NASA.)

Extract the outer ring

$$Q = \begin{cases} TRUE & if \sigma > a \,\&\, 0 < m < b \\ FALSE & otherwise \end{cases}$$

Advanced Approaches for Image Segmentation

Image segmentation is still a research problem that is being investigated by many researchers

General-purpose image segmentation is far from well solved

- Image segmentation by K-means clustering
- Image segmentation with Graphic Models (MRF, CRF, etc.)

Semantic Segmentation with Deep Learning

http://blog.qure.ai/notes/semantic-segmentation-deep-learning-review

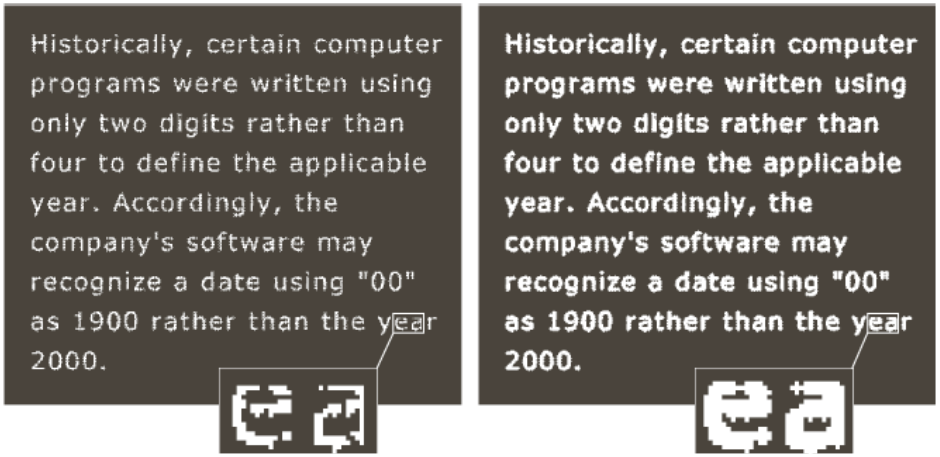
Morphological Image Processing – Techniques to Improve Image Segmentation

Objective: Extract image components for representation and description of region shape including

- Boundaries
- Skeletons
- Convex hull

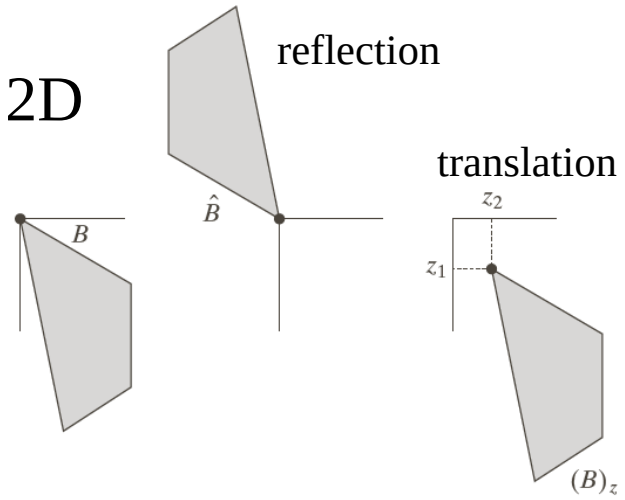
Applications:

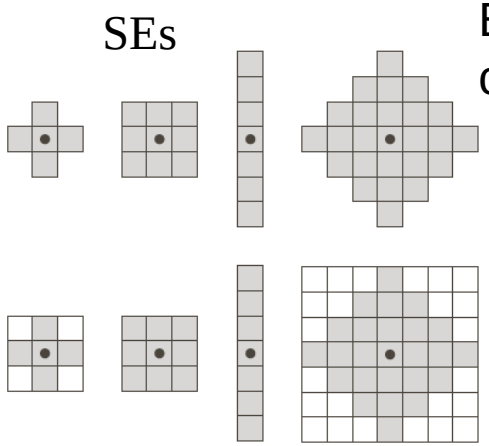
- Edge detection
- Blob/connected component detection



Basic Concepts

- **2D Integer space Z^2**
- **Union, intersection, complement, difference**
- **Set reflection** $\hat{\mathcal{B}} = \{\mathbf{w}|\mathbf{w} = -\mathbf{b}, \mathbf{b} \in \mathcal{B}\}$ $\mathcal{B}$ is a set of 2D points (x, y)
- **Set translation** $(\mathcal{B})_z = \{\mathbf{c}|\mathbf{c} = \mathbf{b} + \mathbf{z}, \mathbf{b} \in \mathcal{B}\}$ -- move the center/origin of $\mathcal{B}$ by **z**
- **Structure elements (SEs): small sets/subimages used in morphology**





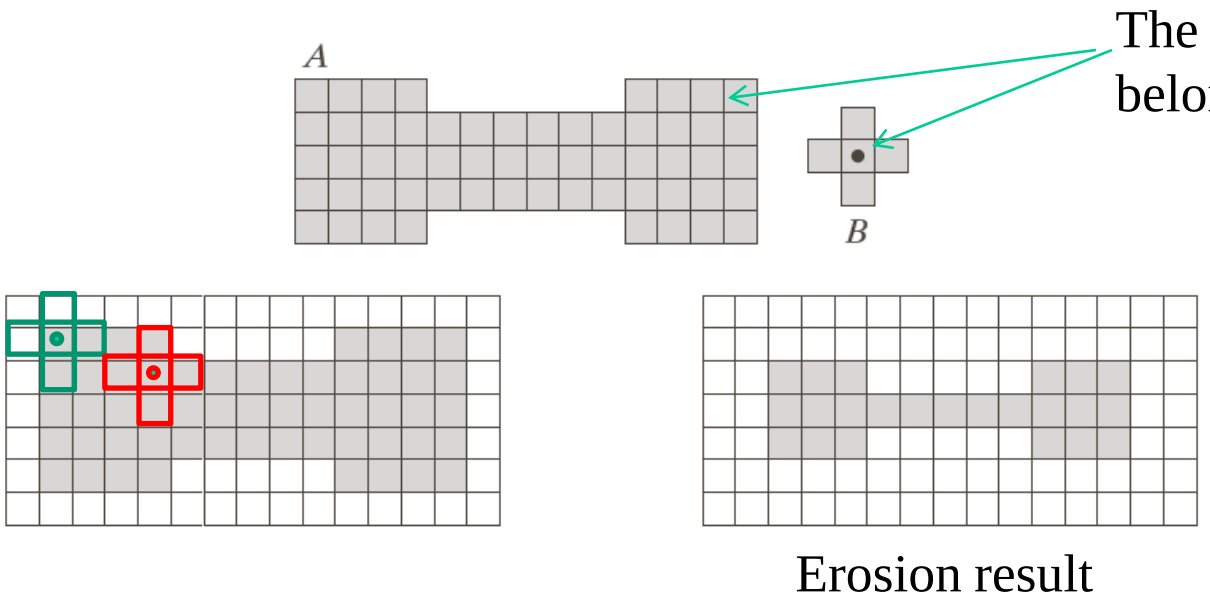
Black dots are centers/origins of SE

SEs for images

An Example of Morphology

Morphology - Create a new set by running B over A so that the origin of B visits every element of A.

An example of erosion: If B is completely contained in A for each operation, the new element is a member of the new set.



Common Morphological Operations

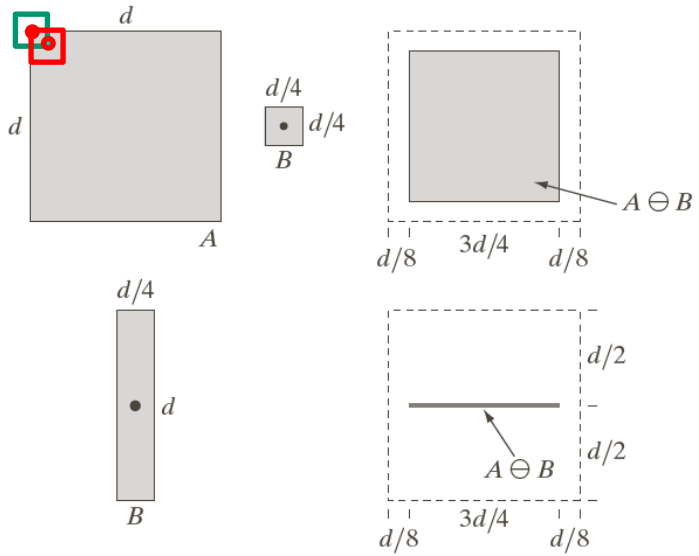
Two basic operations

- Erosion
- Dilation

Other operations

- Opening/closing
- Hit-or-Miss transform
- Thinning/thickening
- Hole filling

Erosion



a b c
d e

FIGURE 9.4 (a) Set A. (b) Square structuring element, B. (c) Erosion of A by B, shown shaded. (d) Elongated structuring element. (e) Erosion of A by B using this element. The dotted border in (c) and (e) is the boundary of set A, shown only for reference.

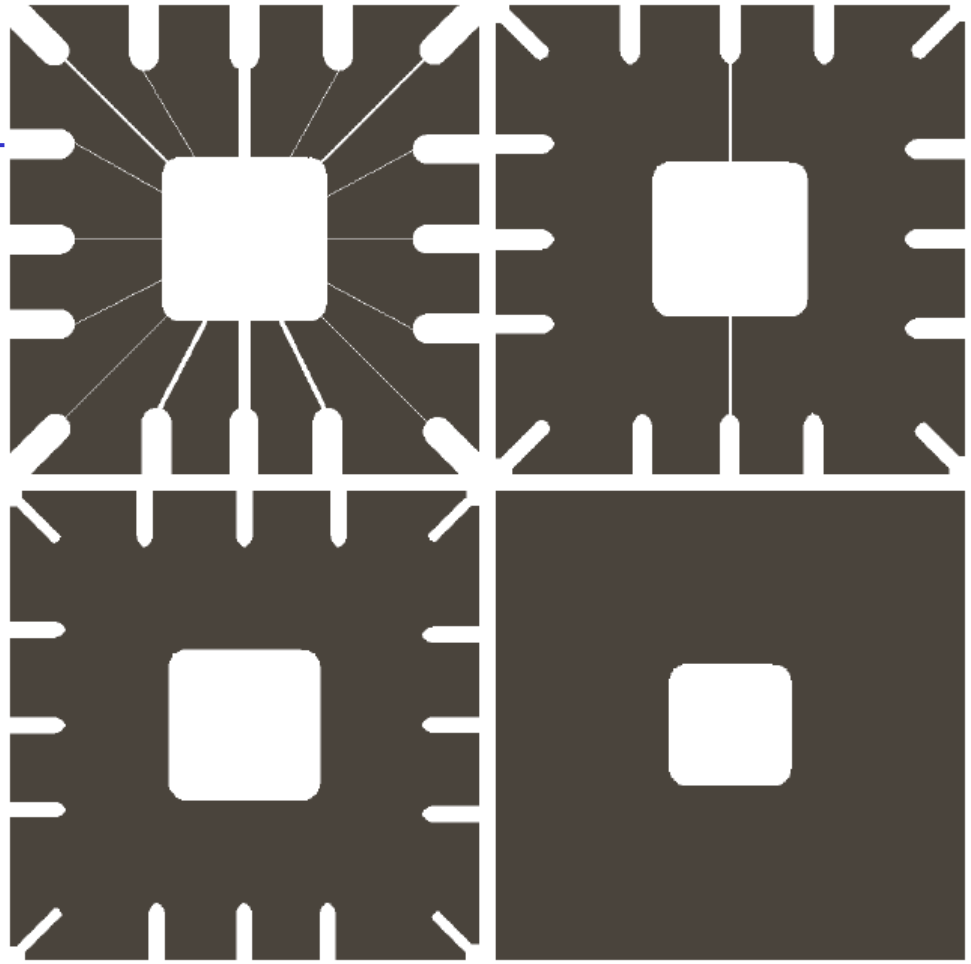
Recall Set Translation

$$(B)_z = \{\mathbf{c} \mid \mathbf{c} = \mathbf{b} + \mathbf{z}, \mathbf{b} \in B\}$$

$$A \ominus B = \{z \mid (B)_z \subseteq A\} \quad \text{or} \quad A \ominus B = \{z \mid (B)_z \cap A^c = \emptyset\}$$

Shrink or thin objects and remove the details smaller than the SE

Erosion



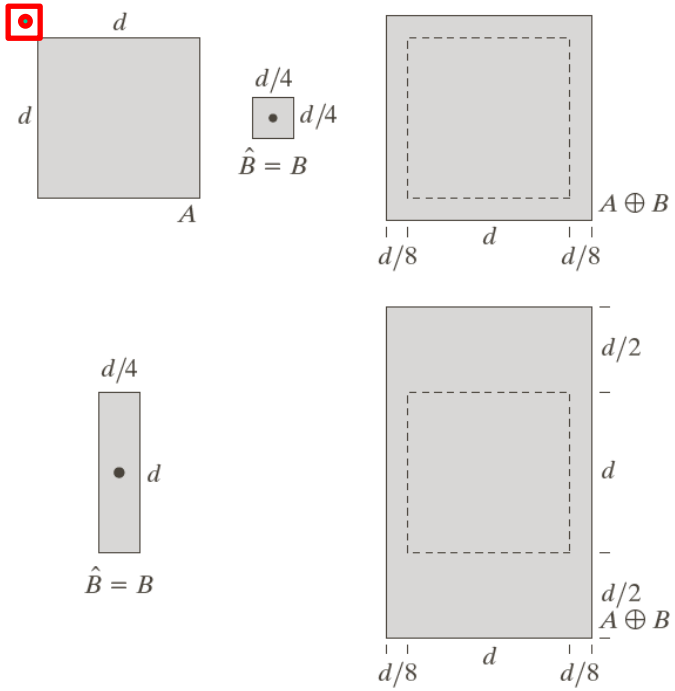
a b
c d

FIGURE 9.5 Using erosion to remove image components. (a) A 486 × 486 binary image of a wire-bond mask. (b)–(d) Image eroded using square structuring elements of sizes 11 × 11, 15 × 15, and 45 × 45, respectively. The elements of the SEs were all 1s.

$$A \ominus B = \{z \mid (B)_z \subseteq A\} \quad \text{or} \quad A \ominus B = \{z \mid (B)_z \cap A^c = \emptyset\}$$

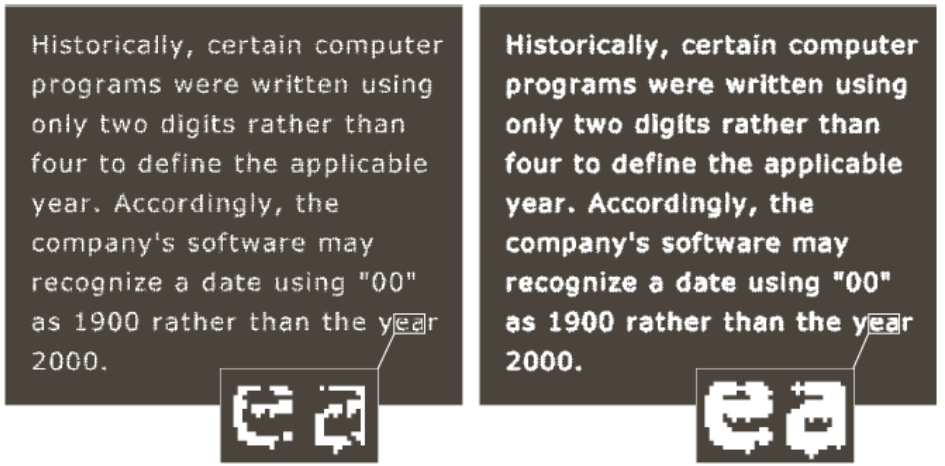
Shrink or thin objects and remove the details smaller than the SE

Dilation



a b c
d e

FIGURE 9.6
(a) Set A.
(b) Square structuring element (the dot denotes the origin).
(c) Dilation of A by B, shown shaded.
(d) Elongated structuring element. (e) Dilation of A using this element. The dotted border in (c) and (e) is the boundary of set A, shown only for reference



0	1	0
1	1	1
0	1	0

Recall set reflection about its origin: $\hat{B} = \{w \mid w = -b, b \in B\}$

$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq 0\} \quad \text{or} \quad A \oplus B = \{z \mid (\hat{B})_z \cap A \subseteq A\}$$

Grows or thickens objects and remove the gaps smaller than the SE

Properties of Dilation

- **Dilation is commutative** $A \oplus B = B \oplus A$

- **Dilation is associative** $A \oplus B \oplus C = A \oplus \left(B \oplus C\right)$

- **Dilation is distributive over the union operation**

$$A \oplus (B \cup C) = (A \oplus B) \cup (A \oplus C)$$

Properties of Erosion and Dilation

- **Erosion** $\boldsymbol{A \ominus B \ominus C = A \ominus (B \oplus C)}$

- **Erosion and dilation are duals of each other**

$$A \oplus B = \left(A^c \ominus \hat{B}\right)^c$$

- $A \subseteq (C \ominus B)$ **if and only if** $(A \oplus B) \subseteq C$

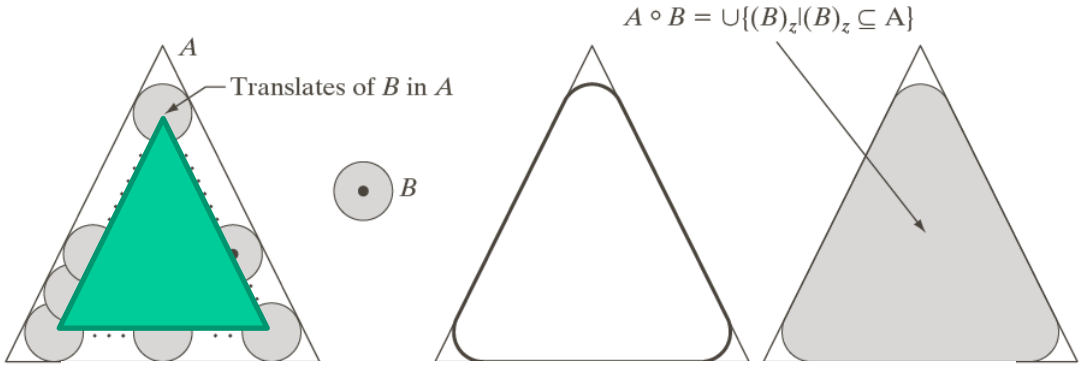
- **If** $A \subseteq C$, $A \oplus B \subseteq C \oplus B$ **and** $A \ominus B \subseteq C \ominus B$

Opening

- **Smooth the contour of an object**
- **Break narrow bridges**
- **Eliminate thin protrusions**

$$A \circ B = (A \ominus B) \oplus B$$
$$(A \circ B) \circ B = A \circ B$$
$$(A \circ B) \subseteq A$$
$$if\ A \subseteq C, A \circ B \subseteq C \circ B$$

$$A \circ B = \cup \{(B)_z | (B)_z \subseteq A\}$$

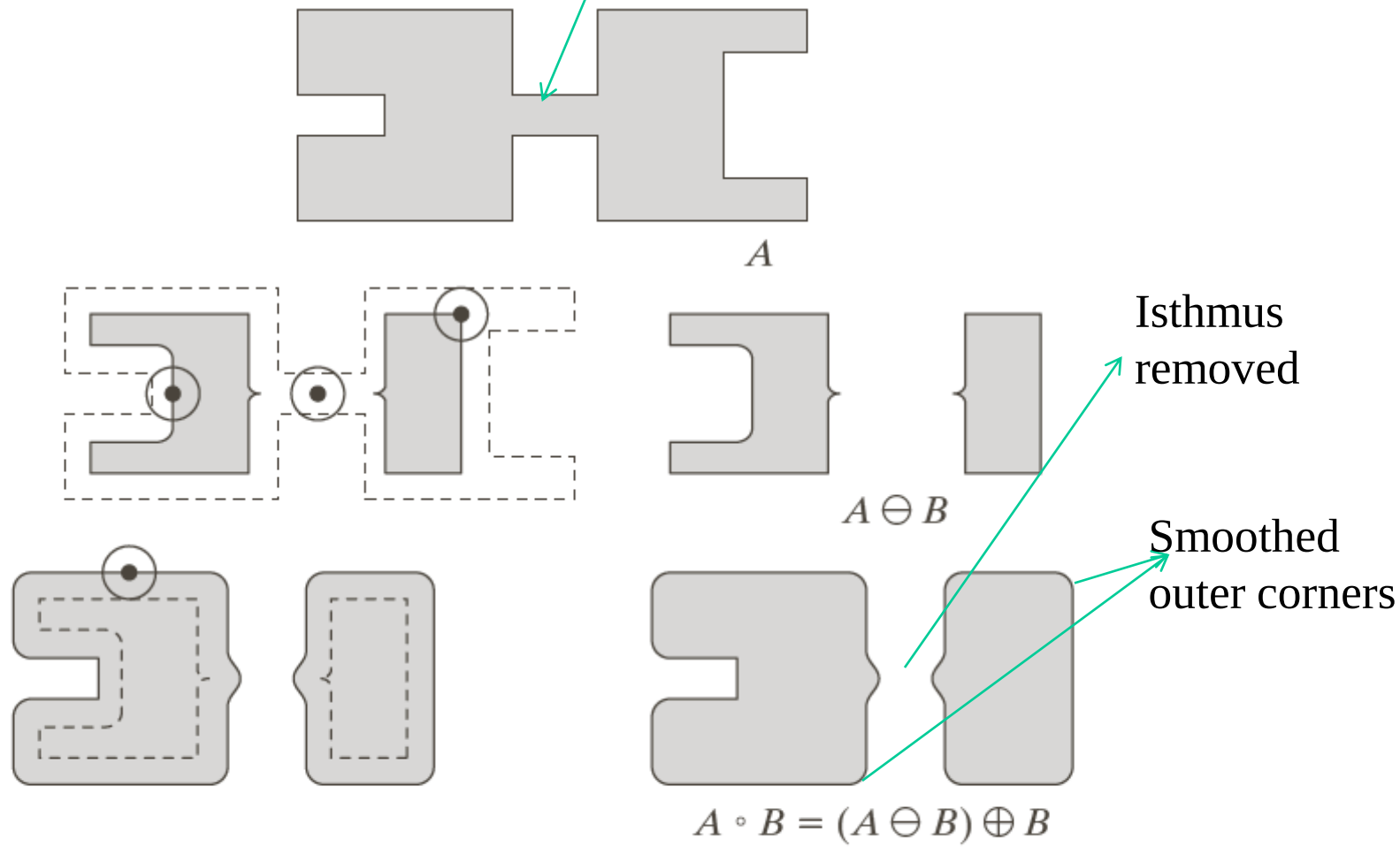


a b c d

FIGURE 9.8 (a) Structuring element B "rolling" along the inner boundary of A (the dot indicates the origin of B). (b) Structuring element. (c) The heavy line is the outer boundary of the opening. (d) Complete opening (shaded). We did not shade A in (a) for clarity.

The SE rolls within the boundary of A.

Opening (Cont'd)



Closing

- **Smooth the contour of an object**
- **Fill narrow breaks and gaps**
- **Eliminate long and thin gulfs**
- **Eliminate small holes**

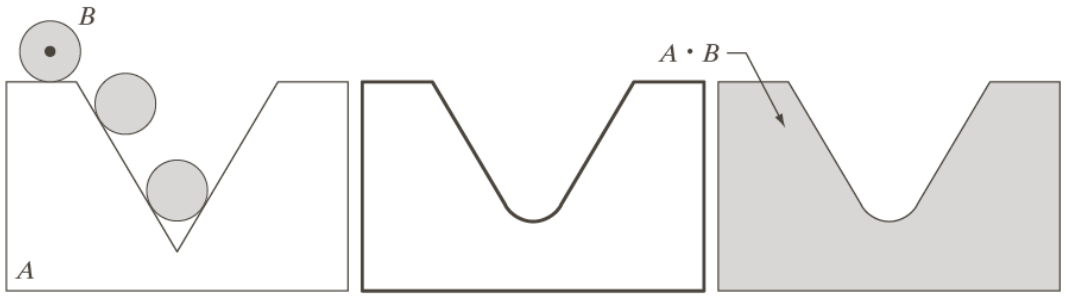
$$A \bullet B = (A \oplus B) \ominus B$$

$$(A \bullet B) \bullet B = A \bullet B$$

$$A \subseteq (A \bullet B)$$

$$if\ A \subseteq C, A \bullet B \subseteq C \bullet B$$

Opening and closing are duals of each other $A \bullet B = (A^c \circ \hat{B})^c$

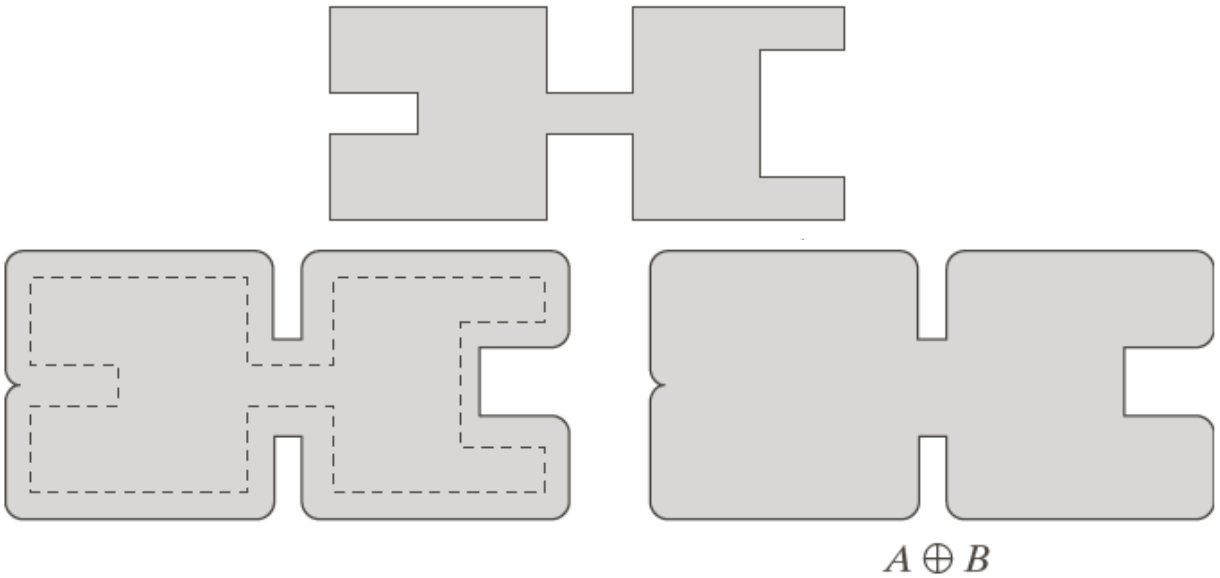


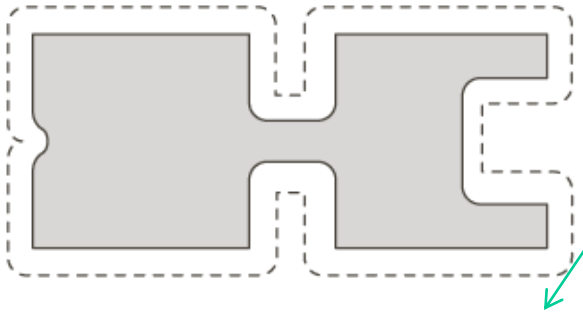
a b c

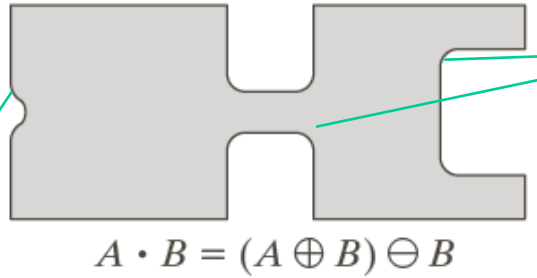
FIGURE 9.9 (a) Structuring element B "rolling" on the outer boundary of set A. (b) The heavy line is the outer boundary of the closing. (c) Complete closing (shaded). We did not shade A in (a) for clarity.

The SE rolls outside the boundary of A.

Closing (Cont'd)



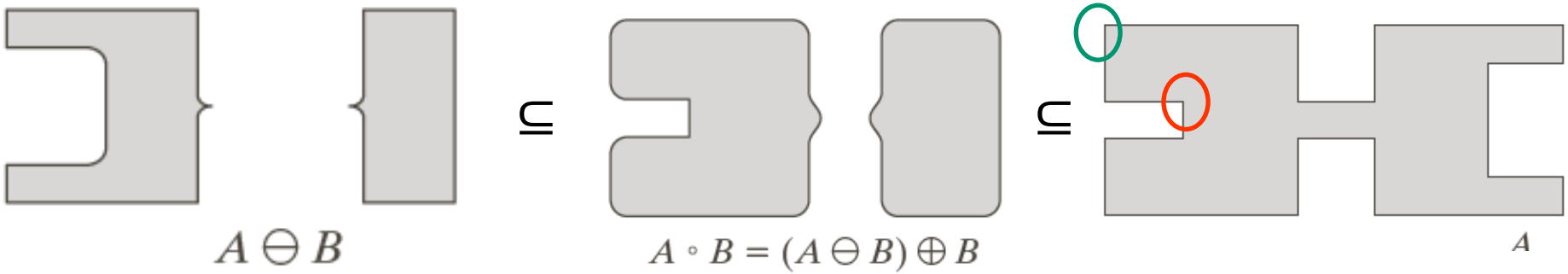


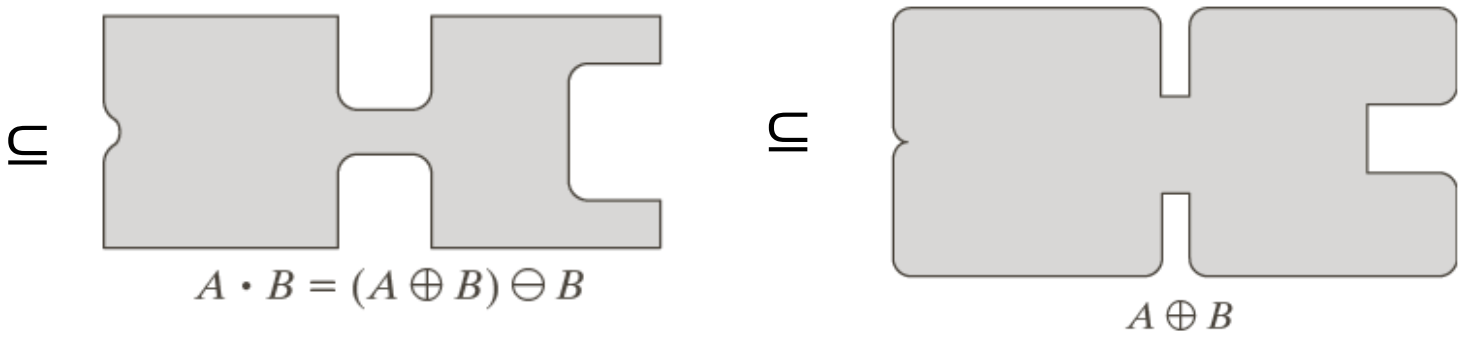


Smoothed inner corners

Eliminated thin gulf

Opening & Closing





$$A \ominus B \subseteq A \circ B \subseteq A \subseteq \quad A \bullet B \subseteq A \oplus B$$

An Example of Opening & Closing

- An opening removes all noise
  - removing the white noise by erosion
  - removing the black noise by dilation
- An additional closing fills the gaps

a b
d c
e f

FIGURE 9.11
(a) Noisy image. (b) Structuring element. (c) Eroded image. (d) Opening of A. (e) Dilation of the opening. (f) Closing of the opening. (Original image courtesy of the National Institute of Standards and Technology.)